NASA Handbook 7010: Direct Field Acoustic Testing

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AEROSPACE

Overview

- In the early 1990's NASA Office of Chief Engineer (OCE) implemented a program to develop NASA-wide standards to provide NASA handbooks to encourage the use of best practices and to support consistent application of engineering issues across the Agency
- Several standards on different disciplines are available for all NASA flight hardware projects and the NASA handbooks are being occasionally updated to reflect advances in the technology
- Under OCE direction a new NASA Handbook 7010 was developed and published in 2016 to provide the best current guidelines for implementation of the DFAT test method
- In this presentation some of the important guidelines summarized in the handbook are discussed in some detail

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The purpose of the 7010 handbook is to provide information and guidelines on the applicability and use of DFAT testing. This handbook is intended to provide an approach which may be consistently followed by those who choose to use this method for qualifying flight hardware for acoustic environments. The handbook describes the following:

- *DFAT testing background.*
- *Configuration.*
- *Instrumentation, test control, and data acquisition and reduction.*
- *Theoretical considerations for designing a DFAT test setup.*
- *Examples discussing the pros and cons of this method of testing.*

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DFAT SOUND GENERATION EQUIPMENT

- The following are considered:
  - *Dimensions of the test article,*
  - *Shape and level of the acoustic specifications,*
  - *Facility layout, and*
  - *Any unique aspects of the test.*
- Section 5 of the handbook discusses sound generation sources such as loudspeakers, woofers, and horns. The basic system components consist of a set of commercial speakers, stereo power amplifiers, and a control system (for more details refer to Larkin and Goldstein).

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INSTRUMENTATION, DATA PROCESSING, AND CONTROL SYSTEMS

- Free-field omni-directional microphones are used for sound pressure measurements.
  - *Microphones should be selected, positioned, and oriented with protection of the test article in mind and to meet the intended acoustic requirement. An adequate number of control microphones are to be positioned circumferentially around the test article at elevations obtained using analytical predictions.*
  - *They should be placed no closer than 0.6 m (2 ft) from the test article surface and no closer than 0.9m (3 ft) from the speakers.*
  - *It is also recommended that an additional reference microphone and a microphone array also be used to further characterize and document the sound field.*
    - The goal is to understand the variations within the sound field and to tune for optimum uniformity by minimizing the constructive and destructive interference of sound waves within the testing volume.

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TEST SETUP AND CHECKOUT PROCEDURES

- Test article on a stand or suspend it from an overhead cable, to be at least 3 ft above the floor and surround it with stacks of loudspeakers.
- Control microphones are to be placed at least 2 ft away from the surface of the test article and at least 3 ft away from the front face of the loudspeakers. This is to minimize the influence of test article surface effects and near-field effects from individual loudspeaker units on the control microphone measurements.
- More details on equipment layout, power required for speakers and data acquisition system, microphone calibration, mass mock up setup, flight hardware test startup, low-level sound field with flight hardware, test duration segmentation are provided in Section 7 of the handbook.

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GUIDELINES FOR DFAT TESTING

The following guidelines are recommended for DFAT to address some of challenges:

- Pre-test Preparation
  - *Model the acoustic field with and without the hardware using analytical and numerical tools discussed in the handbook.*
    - ➢This provides useful knowledge about the acoustic standing waves and interference patterns within the testing volume.
    - ➢Optimizes the location of the loudspeakers and control microphones
    - ➢Identifies empty DFAT volume fundamental acoustic modes below a few hundred Hz
    - ➢Helps to minimize acoustic modal coupling impact.
  - *Use analytical results to design DFAT test setup.*
  - *The minimum space between speakers and the test specimen is to be no less than 1.5m (5 ft).*

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GUIDELINES FOR DFAT TESTING

DFAT Test Setup Preparation (1/2)

- The DFAT setup is to be designed with the information obtained from pre-test analysis.
- A simple mock-up test article and an acoustic array are required to map out the pressure field within the DFAT volume.
  - *Microphone array helps to map out sound pressure variation within the test volume.*
- Position microphones around the test hardware within the DFAT volume at sufficient distances from all surfaces to minimize absorption and re-radiation effects. A distance from any surface of at least ¼ of the wavelength of the lowest frequency of interest is recommended.
- In facilities where this distance cannot be achieved, the microphones shall be located at least ¼ of wavelength from any acoustically responsive surfaces (5 ft discussed above provides ~100 Hz lower frequency).

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GUIDELINES FOR DFAT TESTING

DFAT Test Setup Preparation (2/2)

- The acoustic field near the top of the speakers' stacks exposed to the room should be measured and characterized.
  - *Steps are required to produce more uniform acoustic field if acoustically responsive surfaces, such as reflectors and panels, are located near the top of the DFAT speakers stack. This is the region where the acoustic energy egresses from the test volume, and may result in a lower SPL. If the SPL is too low at the top of the stack, speakers may need to be placed overhead or tilted. Conversely, if there is a big reflecting surface or cavity above the test item, i.e., the facility ceiling, there may be a standing wave resulting in higher pressure at the top of the test item.*
- The SPLs from each control microphone are not to deviate by more than +/-3 dB from the specification input SPLs.
- Perform an acoustic test with a mass simulator and thoroughly examine the structural/acoustic modal coupling at lower frequencies and acoustic field within the speaker circle.

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Flight Hardware Test Setup Preparation

- Once steps discussed in charts #8 and 9 are completed and reviewed by dynamics engineers, the testing may continue with flight hardware. Perform a low-level acoustic test with the hardware and thoroughly examine the structural/acoustic modal coupling at lower frequencies.
- Re-orient test hardware in the DFAT volume, if necessary, to minimize coupling effects; i.e., move sensitive components away from pressure nodes/velocity anti-nodes of the coupled frequencies. For example, the test item may need to be raised to minimize the impact of low-frequency pressure doubling near the floor of the DFAT volume.
- Examine low-level data (both sound pressure and acceleration/strain responses) by extrapolating to the full level (0 dB) acoustic level and proceed if no structural issues are anticipated due to coupling.
- For large test hardware, where re-orientation may not be possible, use additional instrumentation to better gauge the coupling issue.

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Summary

- A new handbook on discussing standard practices for using the DFAT acoustic testing was completed by the author with contribution from NASA centers and industry and was released by NASA headquarters in spring of 2015 as a guidance document.
- The handbook provides engineering information, lessons learned, possible options to address technical issues, classification of similar items, materials, or processes, interpretative direction and techniques, and any other type of guidance information that may help the NASA centers or its contractors in the design, construction, selection, management, support, or operation of systems, products, processes, or services.
- A series of guidelines are provided in the handbook and are briefly discussed in this paper. The control microphone placement is critical to a successful DFAT test because of the known variance in the sound field. The inclusion of more control microphones randomly placed within the testing volume to obtain the control average is critical to narrow the spatial variations. Strong emphasize is given to pre-test preparation and modeling. The important phenomenon that may result in structural failure is the acoustic standing waves coupling with the structural modes. An assessment of such coupling is recommended to be performed through BEM/FEM analysis.

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Thank you

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